nistry of Higher Education and Scientific Research

Al-Mustaqbal University

College of Technology And Health Sciences

Radiological Equipment Techniques

Al-Mustaqbal University

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Radiological Techniques Department

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digital radiography (DDR)

Digital radiography, also known as direct digital radiography, uses x-ray–sensitive plates that directly capture data during the patient examination, immediately transferring it to a computer system without the use of an intermediate cassette as is the case with CR.

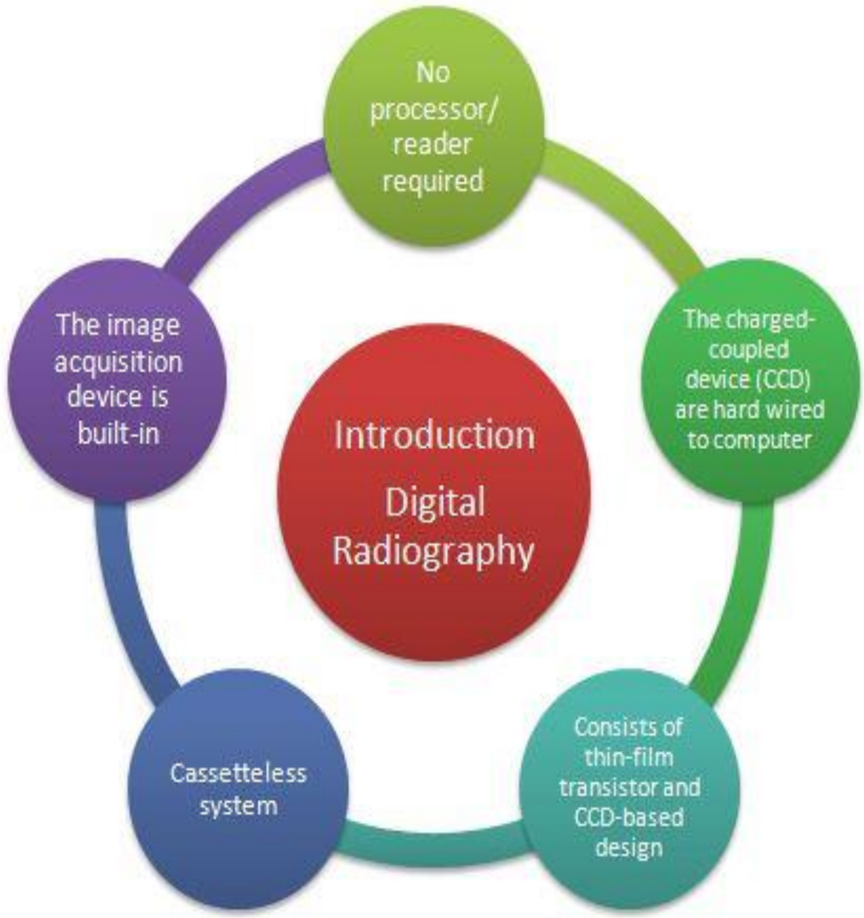

Figure 1

With digital radiography no cassettes are used. The x-rays hit a permanently placed set of hardware, which then sends the digital information directly to a readout mechanism.

Indirect DR: x-ray photons hit a scintillator layer, which then releases light photons that then hit an active matrix array that digitises the signal.

Direct DR: x-ray photons act directly on a photoconductor layer producing positive and negative charge. The positive charge is attracted to a charge capacitor that stores the latent image. It is then read out by TFT switches pixel by pixel.

Direct detectors convert from the x-rays electrons (that are measured), whereas indirect detector convert from x-rays to visible light first and then to electrons (that are measured).

Standard DR process

1- X-ray produced by standard radiographic x-ray tube
2- Image captured by digital image detector
3- Digitised into a stream of data via an analoge-to-digital converter (ADC)
4- Transfer to a system computer
5- Output via digital-to-analoge converter (DAC) to video format
6- Post-processing of image
7- Display on to suitable display device

Indirect DR:

x-ray photons → light photons → electrical signal

Process:

1- X-ray photon hits CsI:TI scintillator layer releasing ~3000 green light photons
2- Light photons detected by active matrix of a-Si :H which is separated into pixels with each pixel containing a photodiode and charge storage capacitor

3- Photodiode – amplifies signal
4- Charge storage capacitor – stores signal of latent image
5- TFT switch – latent image read out and transferred to TFT switches that produce voltage signal that is digitised and converted into the image

Fill factor: TFT and charge storage take up small area of pixel. Fill factor = sensitive area / overall area

Direct DR:

x-ray photons → electrical signal

Process:

1- X-ray photon absorbed by a-Se photoconductor
2- Electrical charge carriers created. The positive charges are drawn to the cathode charge storage capacitor to create latent image
3- Latent image read-out via TFT switches and transferred to bank of charge sensitive amplifiers
4- Voltage signal digitised

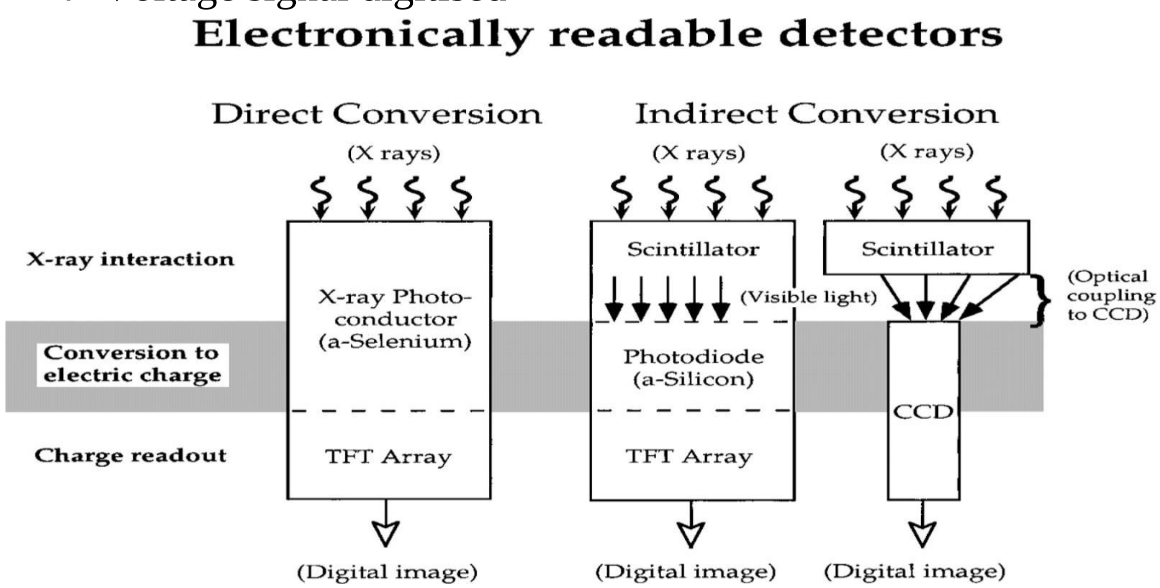

Figure 2

the mechanism of direct digital radiography :

The x-rays hit a permanently placed set of hardware, which then sends the digital information directly to a readout mechanism. Direct DR: x-ray photons act directly on a photoconductor layer producing positive and negative charge. The positive charge is attracted to a charge capacitor that stores the latent image.

Indirect DR

Hardware

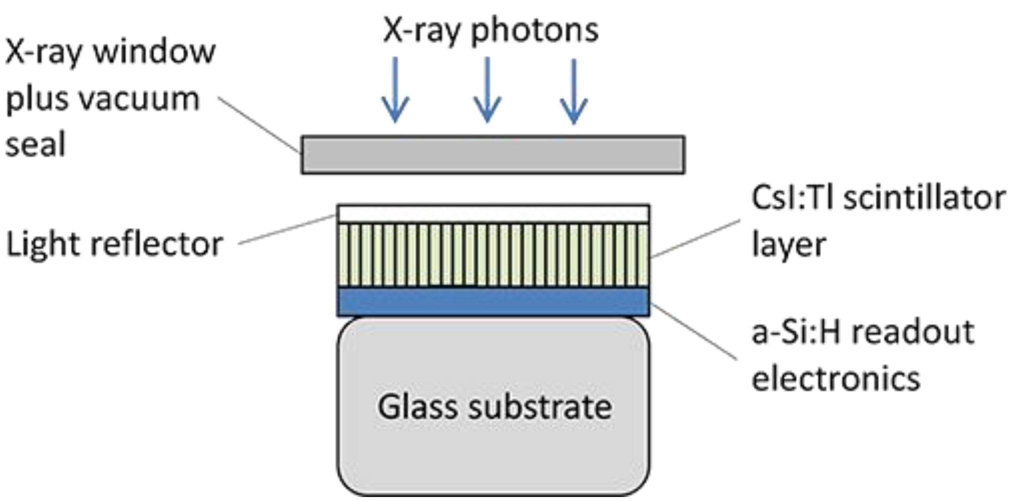

Figure 3

1) Scintillator layer

Most systems use a thin 500 µm layer of caesium iodide (CsI:TI) as a scintillator to capture the image which is coated onto the hydrogenated amorphous silicon (a-Si: H) active matrix array (some systems use gadolinium oxysulfide as the scintillator layer). The CsI:TI is a channeled crystal structure that ensures minimum unsharpness caused by scatter of the recorded image. Absorption of an x-ray photon releases ~3000 light photons in the green part of the spectrum.

2) Active matrix

This is formed by a layer of a-Si: H and forms the readout electronics. The active matrix consists of a high resolution array of electronic components. Each pixel typically comprises a:

- Photodiode (a light sensor) – amplifies signal from incident light photons
- Charge storage capacitor – stores signal of latent image
- Thin-film transistor (or TFT switch) – latent image read out and transferred to TFT switches that produce a voltage signal that is digitised and converted into the image .

This circuitry (TFT and charge storage capacitor) takes up a small area of each pixel preventing image formation in this area. This is calculated by the fill factor.

Fill factor = sensitive area / overall area

Decreasing the pixel size (making each area smaller) improves the resolution but, as the circuitry remains the same size, the fill factor and, therefore, the efficiency of the array, decreases.

3) TFT array

This is a device that amplifies the signal then stores it as an electrical charge. The charge can be released and read by applying a high potential. In the array each transistor corresponds to a pixel.

4) X-ray window

The translucent x-ray window is made of aluminium or carbon fibre over the detector entrance to minimise unnecessary absorption and scatter of x-ray photons.

Image formation

- CsI:TI absorbs x-ray photons and releases light photons
- These light photons are then absorbed in the photodiodes and the charge stored in the charge storage capacitor at each pixel location
- The latent image is read out sequentially to a bank of charge sensitive amplifier (TFT switches)
- The resulting voltage signal is then digitised and transferred to the system computer where the DR image is built up

Direct DR (Direct digital radiography equipment)

A layer of x-ray photoconductor material is used instead of an x-ray scintillator.

Photoconductor

This directly converts x-ray photon energy into free electrical charge carriers (electrons and holes) i.e. the "middle-men" or light photons, are cut out. The most commonly used photoconductor is amorphous selenium (a-Se).

Sequence of image formation

- X-ray photon absorbed by a-Se photoconductor
- Electrical charge carriers (negative electrons and positive holes) are created in the a-Se
- A surface electrode at positive potential attracts and discards all the electrons
- The positive charges are drawn to the charge storage capacitor forming the latent image

- The latent image is then read out sequentially by gating each row of TFT switches (each TFT corresponds to one pixel) in turn to read the charge pattern and transfer to a bank of charge sensitive amplifiers
- The resulting voltage signal is then digitised and transferred to the system computer where the DR image is built up
- Post-processing

Post-processing

Artefacts and correction

Artefacts

- Irregular shading across field: due to non-uniform variations in the sensitivity or gain of the x-ray absorption layer
- Bright / dark spots or lines in image: due to individual rows and/or columns of defective pixels in the active matrix array

Correction

- Gain calibration: uses previously acquired mask image comprising an image acquired with a uniform x-ray beam and subtracting this gain mask image from the patient's image
- Pixel-calibration: defects in pixel array can be corrected by interpolating the data values of neighbouring pixels which are functioning correctly using a reference map

Auto-ranging

The data needs to be matched to the display device.

-Identification of relevant image field

-Generation of a histogram of the data representing the number of pixels at each grey-scale value

-Analysis of the histogram to exclude ranges of data which contain no clinical information (very high and low values)

- Selected grey-scale range normalised to match the display image

Digital image enhancement

Grey-scale modification

A look-up-table (LUT) : is a method of systematically re-mapping the grey-scale values in the recorded image to a new range of values in order to improve the displayed image in some way. Shifting the LUT gradient and position adjusts the mean brightness and displayed contrast of the image.

Spatial feature enhancement

-An unsharp mask algorithm is used to produce a blurred version of the original image

-This is then subtracted from the original image to produce an image which retains only the fine detail structures in the image

-Add the fine detail image back onto the original

-Produces enhanced composite image

Monitor display

- Cathode ray tube (CRT)

Visible image generated by scanning a phosphor screen with a focused beam of electrons all contained within an evacuated glass tube.

- Flat panel displays

Most display monitors are based on liquid crystal technology. Application of the appropriate voltage distribution to an active matrix modulates light polarisation on a pixel-by-pixel basis varying the light emission that comprises the image seen on the screen. It produces a higher contrast image with greater resolution and less power usage.

- Hardcopy

On occasions it is necessary to print a hardcopy image. A hardcopy image is recorded using a laser printer onto a film with silver crystals to create a latent image. This is converted into a visible image by applying heat to the film. This ‘dry’ film processing eliminates the need for traditional chemical processing.